MODELING SURFACE WAVE EFFECTS ON OCEANIC UPPER LAYER STRUCTURES

Le Ngoc Ly
Department of Oceanography
Naval Postgraduate School
Monterey, CA 93943-5100 USA
Tel: (408) 656-1003; Fax1 (408)656-1003
Fax2: (408) 656-2712
E-mail: lely@nps.navy.mil

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LONG-TERM GOALS

The long term goals of this program are studies of air-wave-sea (AWS) interaction relationships and applications of developed theories to larger oceanic and atmospheric models using coupled AWS interaction models.

OBJECTIVES

This program seeks new theories in AWS interaction in developing numerical models for studying influences of ocean waves on surface fluxes, dynamical and structures of the air-sea system using both semi-empirical theory of and a new theory, wave boundary layer theory, to air-sea coupling. It includes study of surface wave effects using Ly's (1995; 1997a,b,c) newly-developed coupled AWS interaction model.

APPROACH

In contrast to atmospheric boundary layers over the land, where mean velocity is the main source of turbulence energy, the turbulence in the upper the of ocean is governed not only by mean velocity shear, but also by waves. The ocean surface wave effects can be taken into boundary layer models using (1) semi-empirical theory of turbulence (Ly, 1995; 1997a,b,c; Benilov, Ly, 1997a,b); (2) wave-induced stresses of the wave boundary layer (WBL) . In the semi-empirical theory of turbulence, the action of surface waves is modeled by both mean and turbulent kinetic energy (TKE) at the air-sea interface (Ly, 1990; 1986), by TKE flux (Kundu, 1980; Klein and, 1981, Craig and Banner 1994; Craig, 1996) and by turbulent kinetic dissipation of breaking waves (Ly, 1995; 1997a,b,c). In the approach of the wave boundary layer theory, surface ocean wave effects are taken into account by expressing the Reynold's stress in terms of the and wave-induced stresses.

WORK COMPLETED

Our work develops a new direction in air-sea interaction: air-wave-sea theory and modeling. A mathematical, computer coupled model of wave-sea interaction has been developed for studying influences of ocean waves on dynamical, turbulent structures of the air-sea system and impacts on coupled modeling. Some numerical experiments were carried out to study surface wave-enhanced turbulent structures in the ocean and to compare with available data.

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RESULTS

A mathematical coupled model of air-sea-wave interaction is developed to study influences of ocean surface waves on dynamical, turbulent structures of air-sea system and their impacts on coupled modeling. In the model, surface waves are considered as another source of turbulent energy in the upper of the ocean besides turbulent energy from shear production. The turbulent dissipation (diss) at the ocean surface is written in the form of a linear of terms representing dissipation from mean flow and breaking waves. The diss from breaking waves is estimated by using similarity theory and data, and is written in terms of wave parameters such as wave phase, height, and length, which then are expressed in terms of friction by using similarity theory. The model can predict diss distributions in the upper ocean turbulent layer (UOTL) which agrees very well with the observations of the law of -4 power by Gargett (1989). The law of -4 power is also observed by various investigators. This law was believed to be evidence of the inadequacy of the stress boundary layer theory in diss predictions. Numerical studies also show that wind (wave) and diffusion have an important role in driving diss distributions away from a log law of the classical wall-layer theory. simulations also confirmed that the model can accurately predict diss with various distribution laws depending on surface wave conditions and diffusion, the model shows good agreement with measurements and observations of diss distributions, wind stress, roughness length, and geostrophic drag coefficients under ocean wave conditions.

IMPACT/APPLICATIONS

The model outputs are compared with observed data. The model and its results, can be applied to larger scale oceanic and atmospheric models. The model results are important for satellite sending of the global wind, temperature, surface wave fields, and for surface flux estimations by using bulk transfer coefficients.

Our turbulent scheme with breaking waves is applied to a ocean circulation model by Ly's project in ocean modeling. This ocean model will allow us to study effects of surface breaking waves on current, turbulent and thermodynamical structures in real oceans.

TRANSITIONS

The turbulent scheme with breaking waves is transferred to Ly's project in ocean modeling.

RELATED PROJECTS

This program is closely related to Ly's NOMP coastal ocean modeling program. This program is also related to the Stevens Institute of Technology efforts (Benilov) on wave and turbulent studies.

REFERENCES

Benilov, A. Y. and Ly, L.N. 1997a: Dynamic structure of the upper ocean under effects of the surface waves and their breaking. Physics of Fluids. (Submitted).

Benilov, A. Yu. and Ly, L.N. 1997b: The ocean upper layer with the presence of the surface waves and their breaking. AGU Spring Meeting, May, 97,, Maryland. Transactions, OS52A-10.

Craig, P. D. and Banner, M. L., 1994: Modeling wave-enhanced turbulence in ocean surface layer. J. Phys. Oceanogr., 12, 2546-2559.

Craig, P. D. 1996: Velocity profiles and surface roughness under waves. J. Geophys. Res., 101, 1265-1277.

Gargett, A. E., 1989: Ocean turbulence. Annual Review of Fluid, Vol. 21, 419-451.

Klein, P. and Coantic, M., 1981: A numerical study of turbulent process the marine upper layer. J. Phys. Oceanogr., 11, 849-863.

Kundu, K.P., 1980: A numerical investigation of mixed-layer dynamics. J. Phys. Oceanogr., 10, 220-236.

Ly, L. N. 1995: A numerical coupled model for studying air-sea-wave. Phys. Fluids, 7 (10), 2396-2406.

Ly, L.N. 1997a: A Numerical Study of aerodynamic roughness as seen from above and below in air-sea coupling. Fluid Dynamics Res. (In Press).

Ly, L.N. 1997b: Modeling wave-enhanced turbulence in the upper oceanic. J. Fluid Mech. (Submitted).

Ly, L.N. 1997c: Aerodynamic roughness from above and below in air-sea coupling. AGU Fall Meeting, San Francisco, CA.

Smith, S. D., R. J. Anderson, W. A. Oost, C. Kraan, N. Maat,. DeCosmo, K. B. Katsaros, K. L. Davidson, K. Bumke, L. Hasse, and H. M., 1992: Sea surface wind stress and drag coefficients: The HEXOS results Boundary-Layer Meteorol., 60, 109-142.

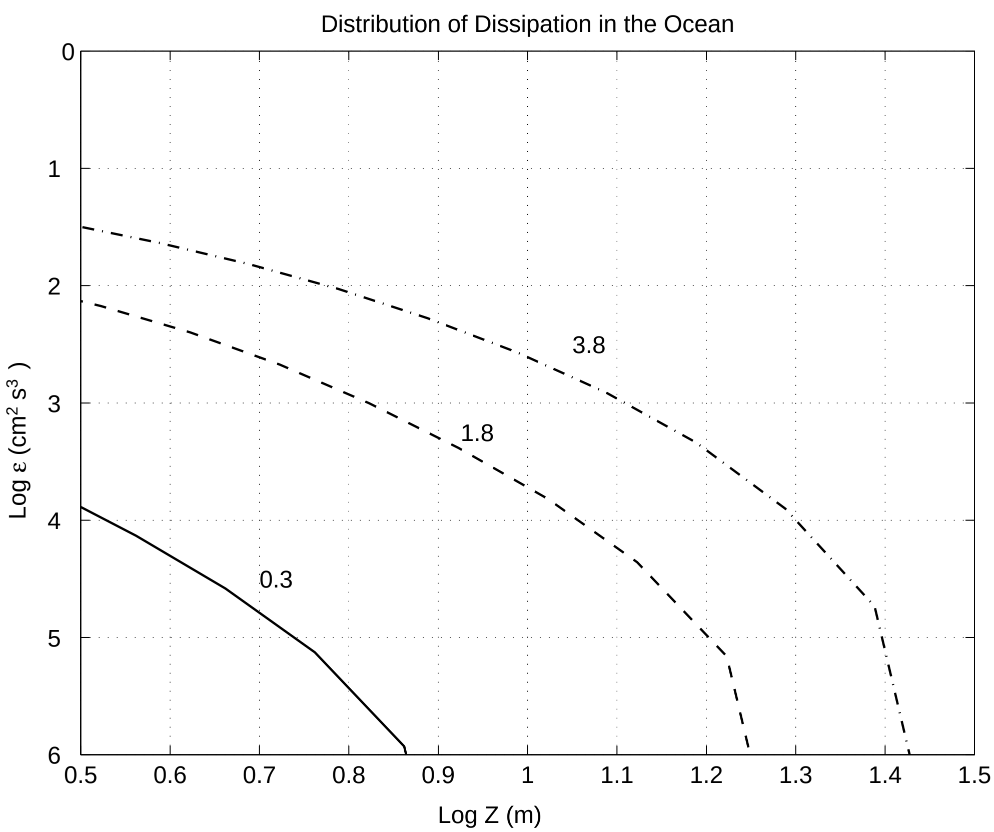

Fig. 1 Distributions of turbulent dissipation at the ocean surface at various surface wave heights.

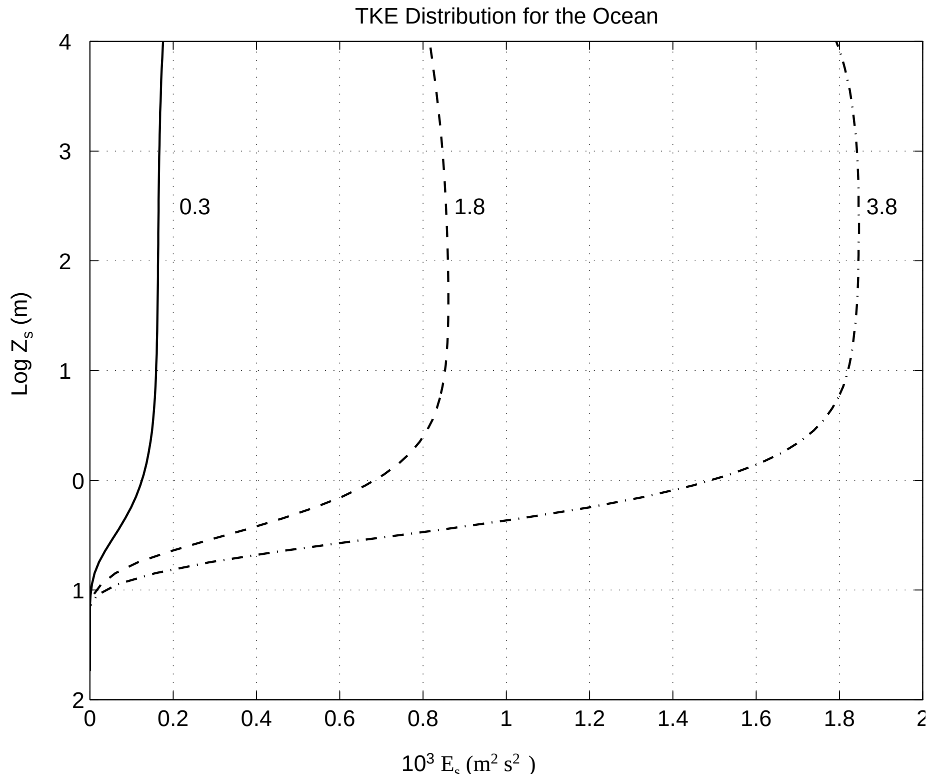

Fig. 2 Distributions of turbulent kinetic energy at the ocean surface at various wave heights.

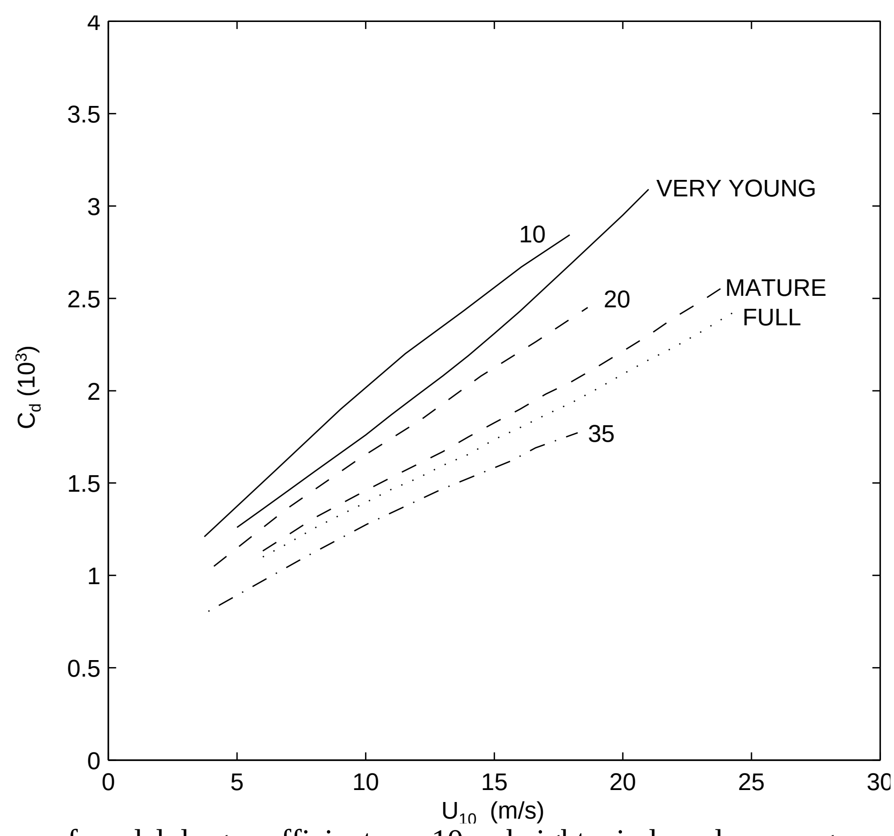

Fig. 3 Dependence of model drag coefficients on 10-m height winds and wave ages equal to 10, 20, and 35 computed by the model. Three curves with "very young", "mature" and "full" from observational data by Smith et al. (1992).